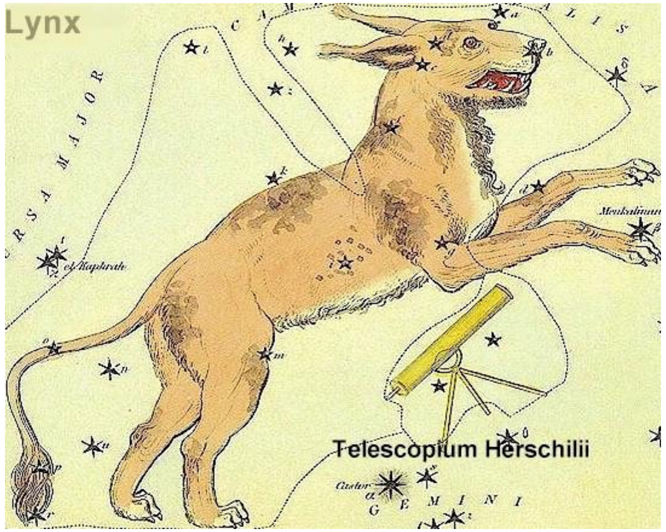
Lynx Mission Concept Status

Jessica A. Gaskin (NASA MSFC)

Presented on behalf of the Lynx Team



Community STDT
F. Özel, Arizona (Co-Chair)
A. Vikhlinin, SAO (Co-Chair)

S. Allen, Stanford
M. Bautz, MIT
W. N. Brandt, Penn State
J. Bregman, Michigan
M. Donahue, MSU
J. Gaskin, MSFC (Study Sci.)
Z. Haiman, Columbia
R. Hickox, Dartmouth
T. Jeltema, UCSC
J. Kollmeier, OCIW
A. Kravtsov, U. Chicago
L. Lopez, Ohio State
R. Osten, STScI
F. Paerels, Columbia
D. Pooley, Trinity
A. Ptak, GSFC
E. Quataert, Berkeley
C. Reynolds, UMD
D. Stern, JPL

- A symbol of great insight with the ability to see through solid objects to **reveal the true nature of things**.
- Much of the baryonic matter and the settings of the most active energy release in the Universe are visible primarily or exclusively in the X-rays

Lynx and the Concept Study

The *Lynx* X-Ray Observatory

- × 50 higher throughput while maintaining *Chandra's* angular resolution.
- × 16 larger solid angle for sub-arcsec imaging
- × 800 higher survey speed at the *Chandra* Deep Field limit
- × ~1000 more power in grating spectroscopy
- High-resolution, spatially resolved spectroscopy on fine scales

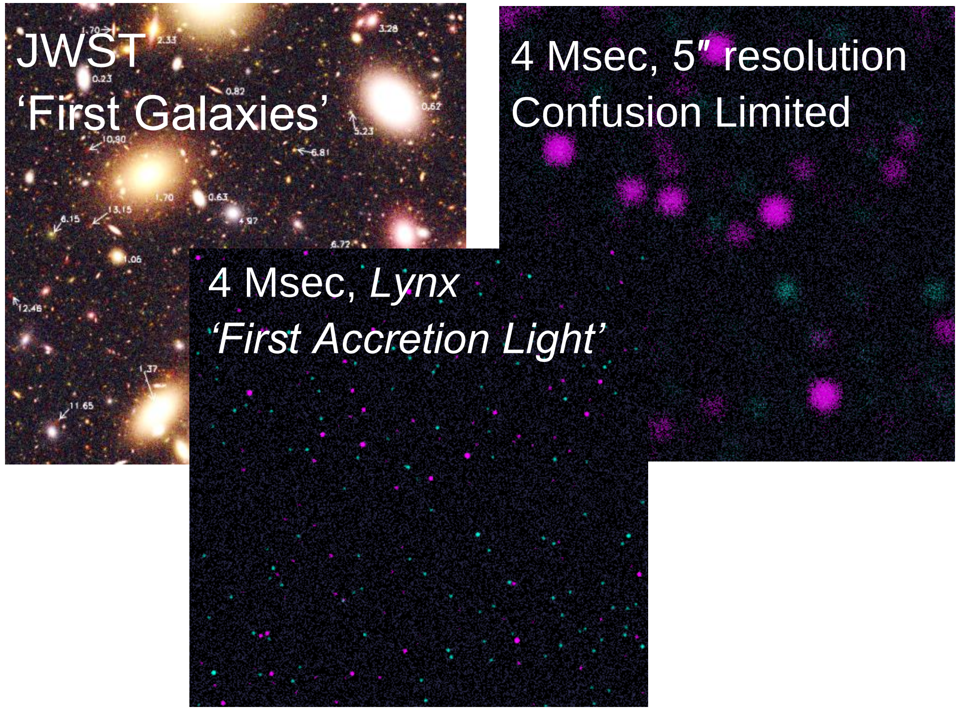
Astro2020 Decadal Study Output:

1. A **science case** for the mission
2. A **notional mission** and observatory, including a report on any tradeoff analyses
3. A **design reference mission**, including strawman payload trade studies.
4. A **technology assessment** including: current status, roadmap for maturation & resources
5. A **cost assessment** and listing of the top technical risks to delivering the science capabilities
6. A **top level schedule** including a notional launch date and top schedule risks.

The Dawn of Black Holes

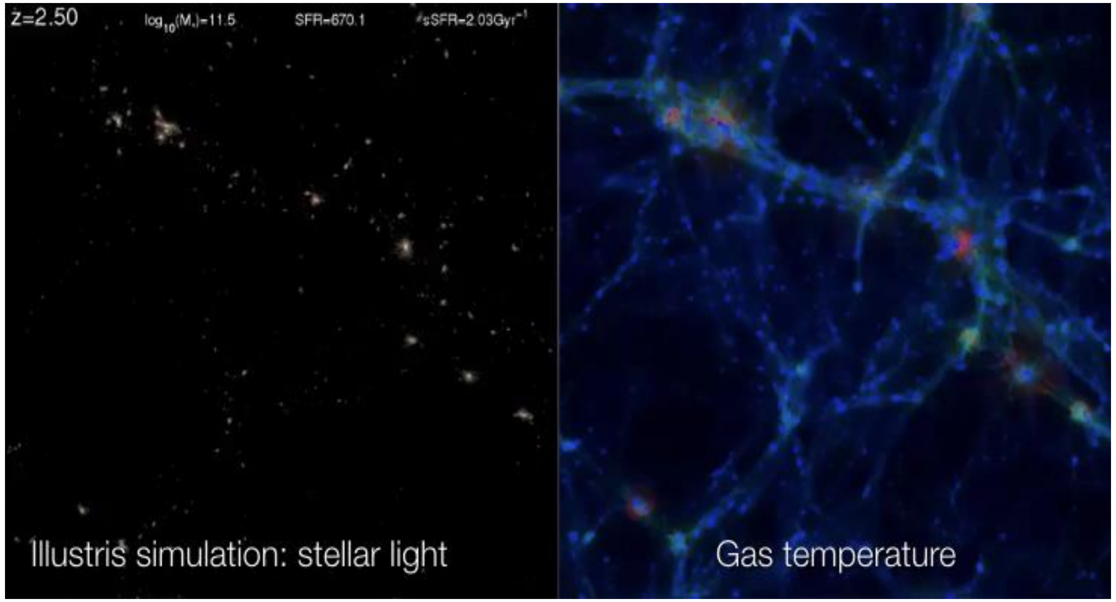
Lynx will observe the birth of the first seed black holes at redshift up to 10 and provide a census of the massive black hole population in the local and distant universe, follow their growth and assembly across cosmic time, and measure the impact of their energy input on all scales. Of interest to all astronomers working on the early universe, galaxy formation, black holes.

Simulated 2x2 arcmin deep fields



The Invisible Drivers Behind Galaxy Formation and Evolution

The assembly, growth, and the state of visible matter in the cosmic structures is largely driven by violent processes that produce energy that heats the gas in the CGM and IGM. The exquisite spectral and angular resolution of *Lynx* will make it a unique instrument for mapping the hot gas around galaxies and in the Cosmic Web.



Facility Class Science

Exploration Science with a Rich Community-Driven Observer Program!

- First Black Holes and their Co-evolution with Galaxies
- Cycles of (Hot) Baryons in and out of Galaxies
- Feedback from Stars, Supernovae, and Black Holes
- Origin and Evolution of Stars and their Local Environments
- X-ray Counterparts of GW Events and Multi-Wavelength Phenomena
- Physics of Accretion and Compact Objects

Lynx Optical Assembly

High-resolution X-ray Optical Assembly: 3 Viable Architectures – Trade Study

- Meta-Shell Si Optics (W. Zhang/GSFC)
- Adjustable Optics (P. Reid/SAO)
- Full Shell (K. Kilaru/USRA, G. Pareschi (Brera)

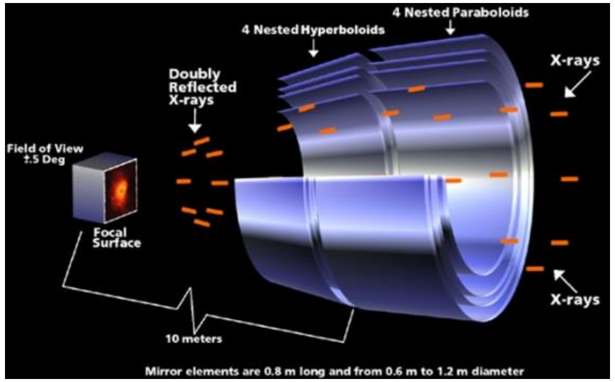
OWG will make a formal recommendation to STDT: 6/1/18
STDT Finalizes their decision: 7/1/18

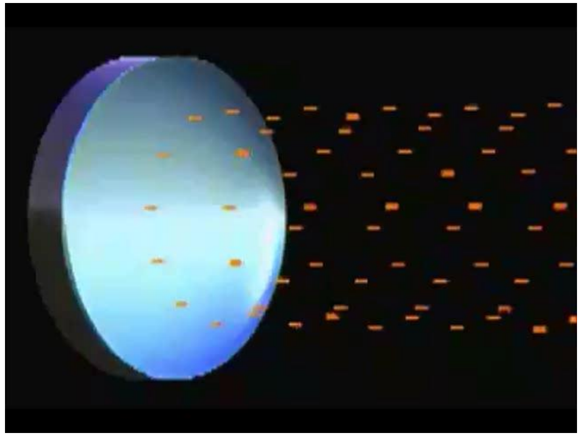
Up-select will be based on Science, Technical and Programmatic criteria (TBF)

- *Does the configuration Satisfy Science Requirements?*
- *Is there a feasible path for development?*
- *Are there existing X-ray measurements and/or analyses?*
- *Can it interface with the spacecraft and survive launch?*

Science Driven Requirements

Lynx Optical Assembly	
Angular resolution (on-axis)	0.5 arcsec" HPD (or better)
Effective area @ 1 keV	2 m^2 (met with 3-m OD)
Off-axis PSF (grasp), A*(FOV for HPD < 1 arcsec)	≥ 2 m^2 * 300 $arcmin^2$
Wide FOV sub-arcsec Imaging	10 arcmin radius





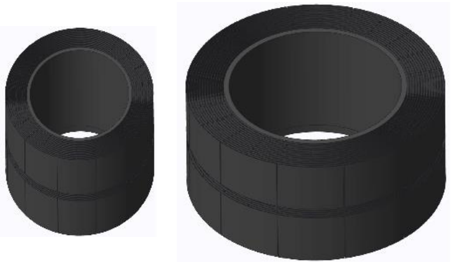
CXC/D. Berry

Meta-Shell Approach

(Zhang et al. NASA/GSFC)

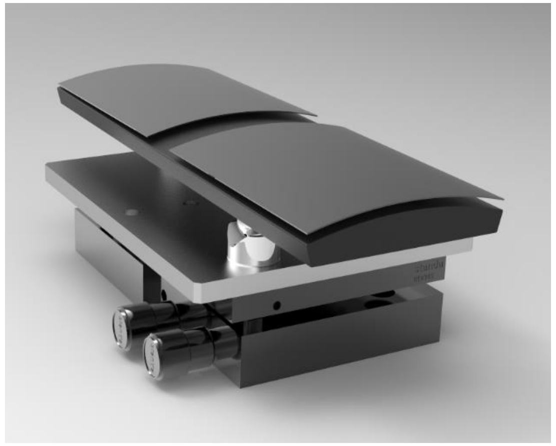
Component	Predicted Contribution to HPD (“)	
	Lynx Rqrmnt	Status
Mirror segments	0.2	2.0
Alignment	0.1	1.5
Bonding	0.1	0.5
Thermal	0.2	0.2
Gravity release	0.1	0.1
Total	**0.3**	**2.5**

Segments

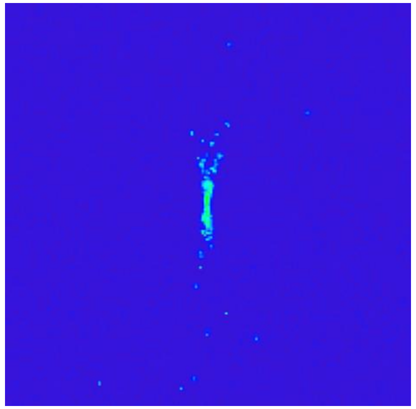


Meta-shells

Assembly



Single-Pair X-ray Test Module

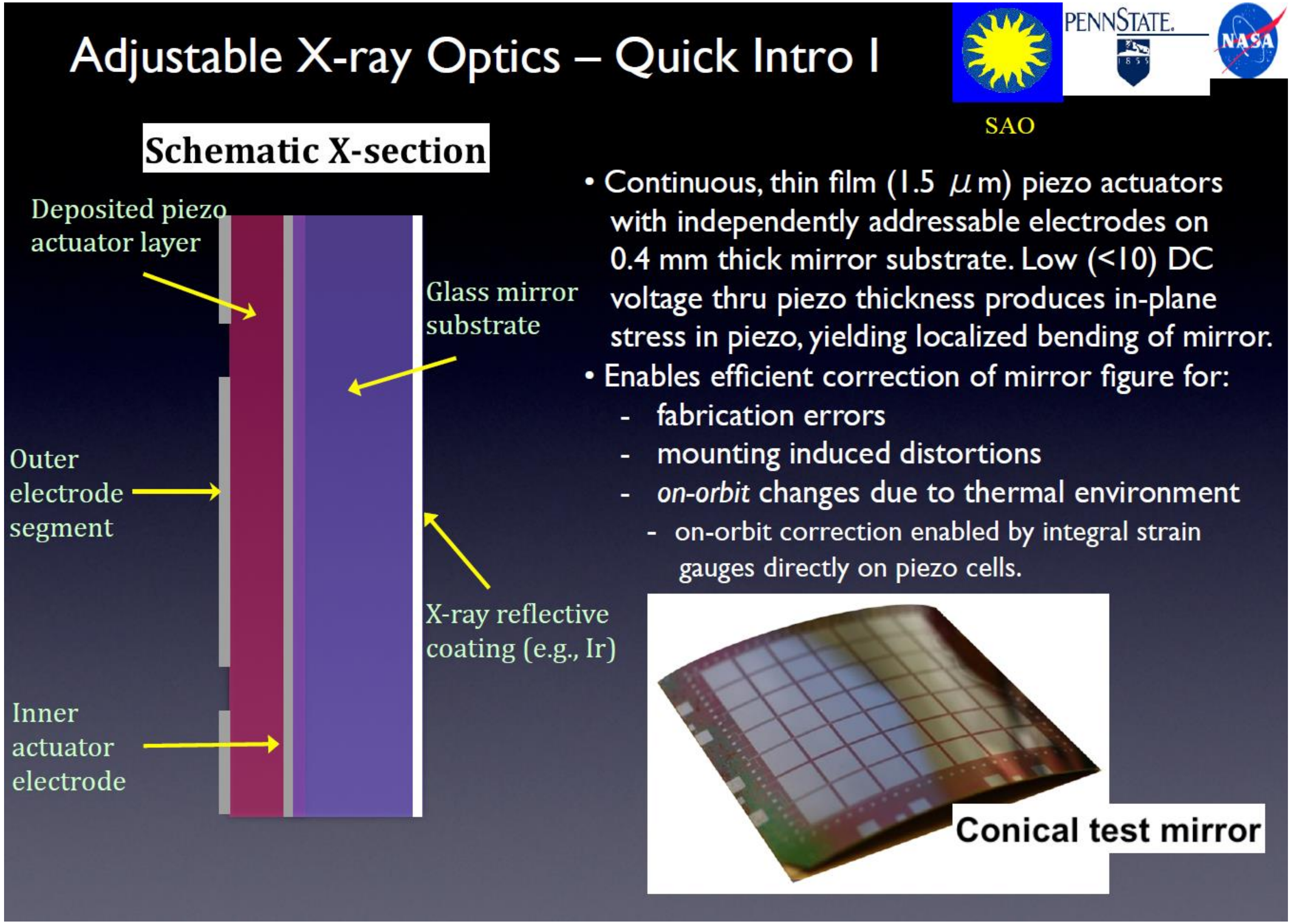


Full Illumination 4.5keV X-rays 3.8” HPD

See Talks:

Adjustable Shell Approach

(Reid et al. SAO)



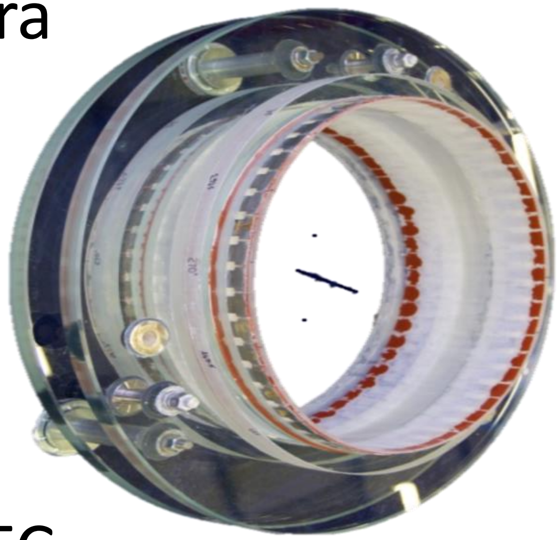
See Talks: ….

Design Parameters:

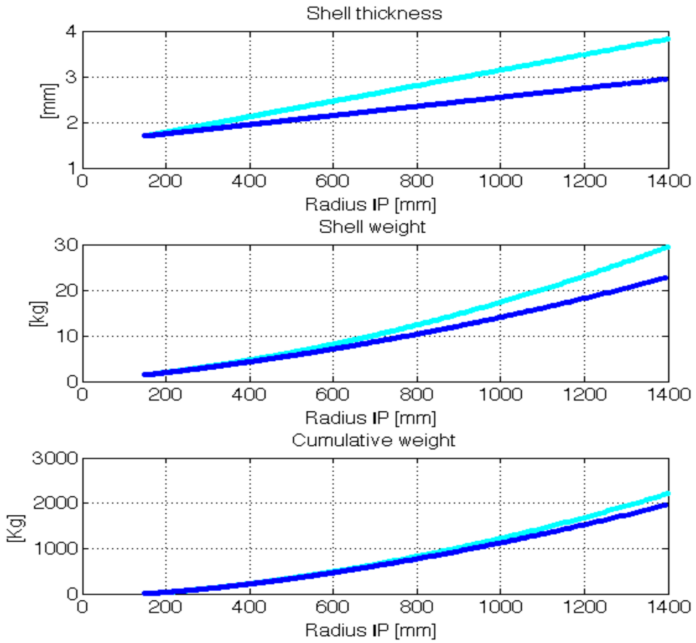
- Wolter-Schwarzschild
- 3 radial sets of modules (inner, middle, outer) ranging from 200 mm radius to 1500 mm radius
- 292 shells (allowing for space between module rows
- 42 modules (6 inner, 12 middle, 24 outer)
- ~8200 segments (P and S combined)
- Azimuthal spans range from ~200 mm to ~400 mm
- Axial length 200 mm
- ~ 10^7 piezoelectric adjuster cells in total
- Modeled performance"2.3 m^2 @ 1 keV with Ir coating

Full shell Optical Design

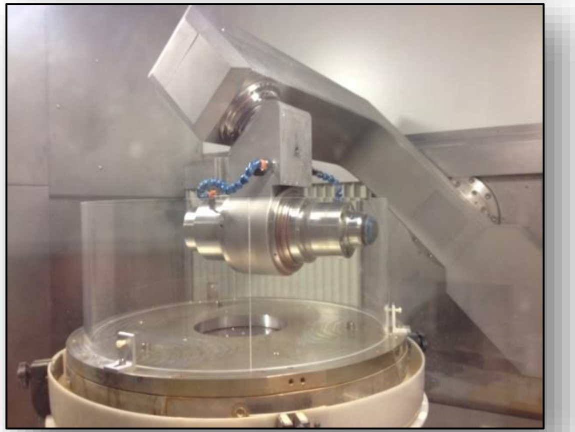
Brera



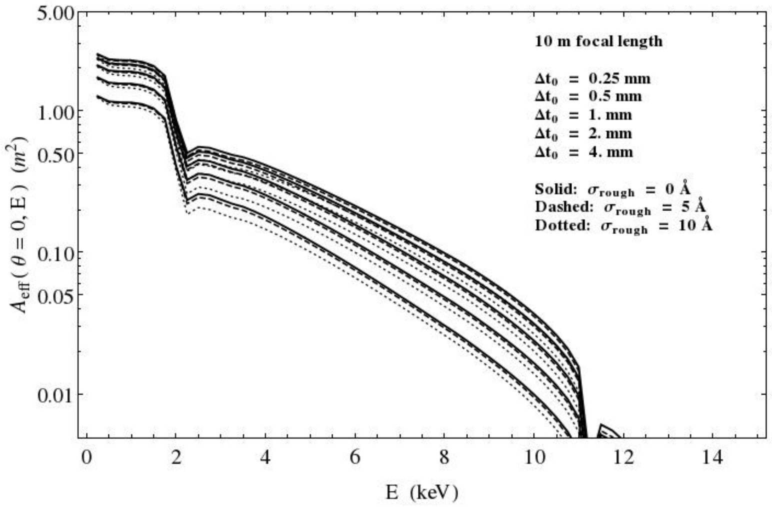
- Fused Silica: low density, low CTE
- Procure high-quality quartz (or, hot slump)
- Fine-grinding to 1.5µm OOR (P-V) + polish to 5-6 nm RMS microroughness
- Ion beam figuring corrections
- Coating



MSFC

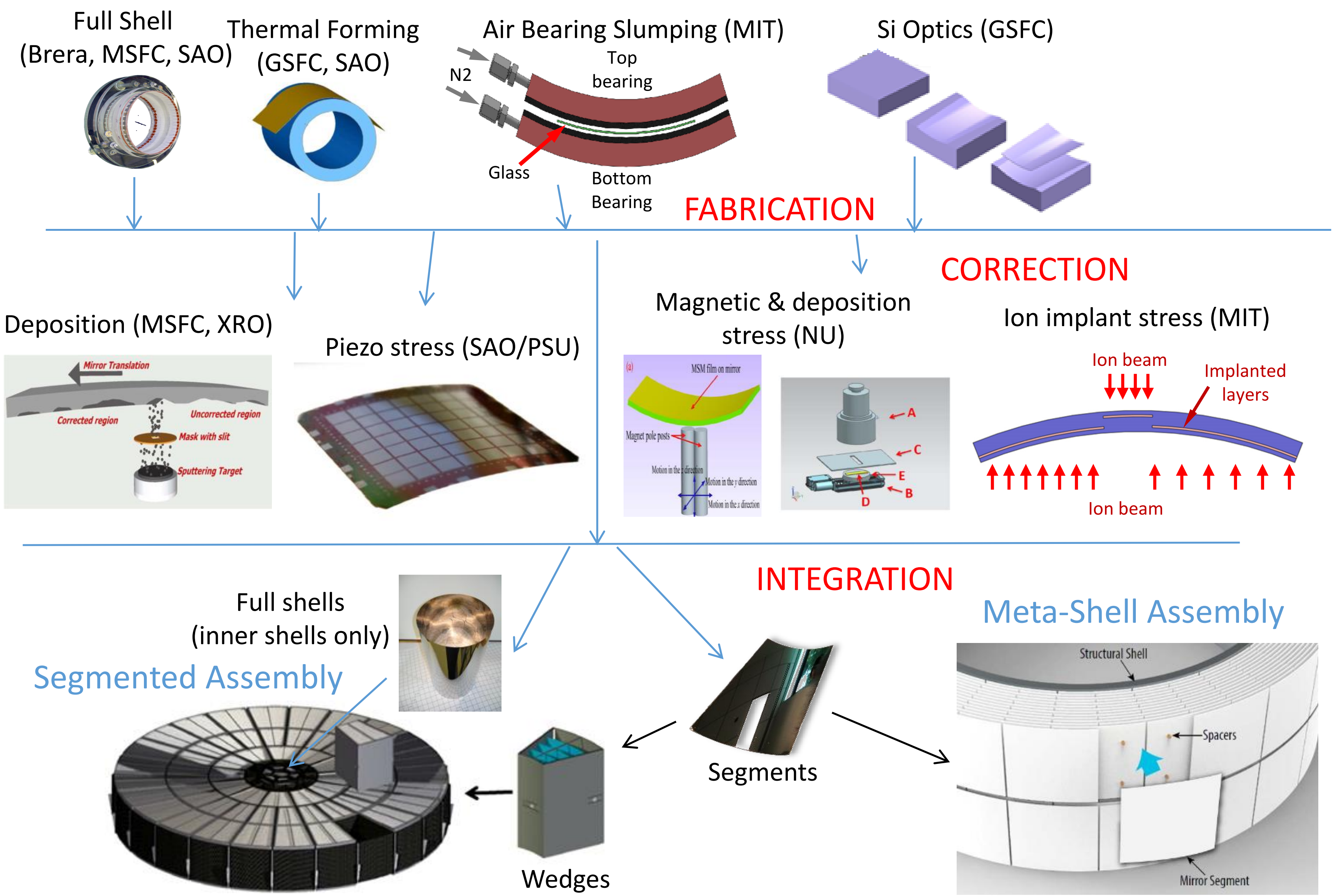


- Be, BeAl: low density, CTE; high modulus, yield strength
- Procure diamond-turned, heat treated, NiP coated shells (<100µm RMS)
- Diamond-turn and Zeeko polish
- Differential deposition corrections



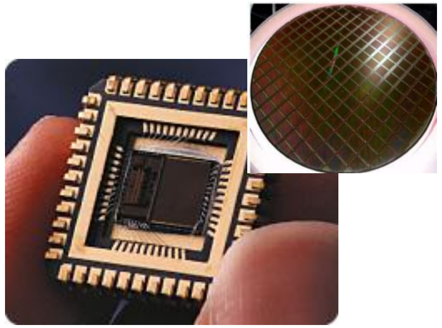
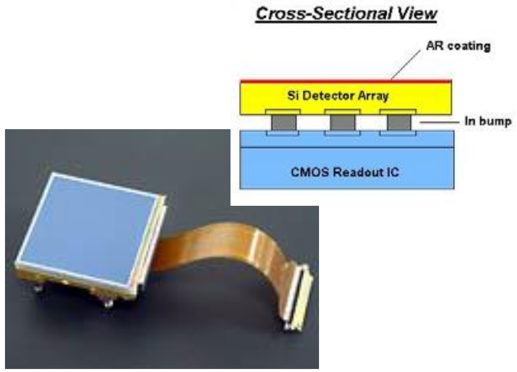
See Talks:

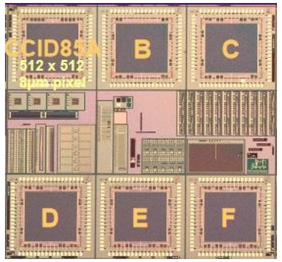
Lynx Optical Assembly



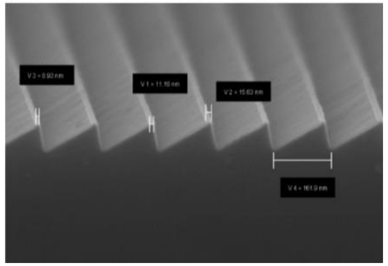
Lynx Science Instruments

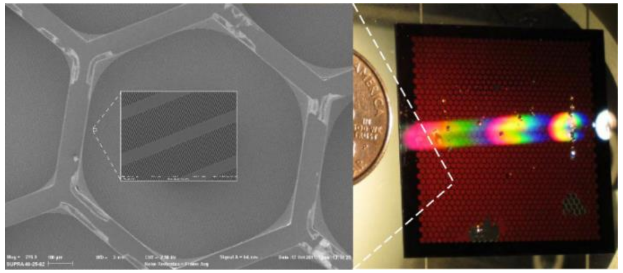
- High Definition X-ray Imager (HDXI)
    - Instrument Design and Integration (On-going @ MSFC ACO)

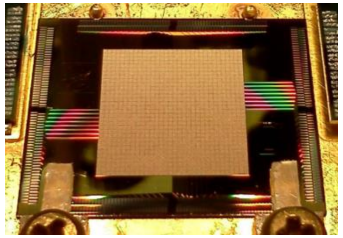


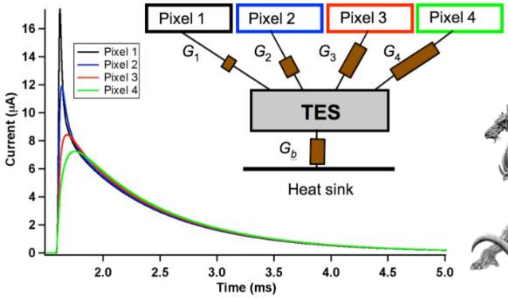
- X-Ray Grating Spectrometer (XGS)
    - Instrument Design and Integration (On-going @ MSFC ACO)





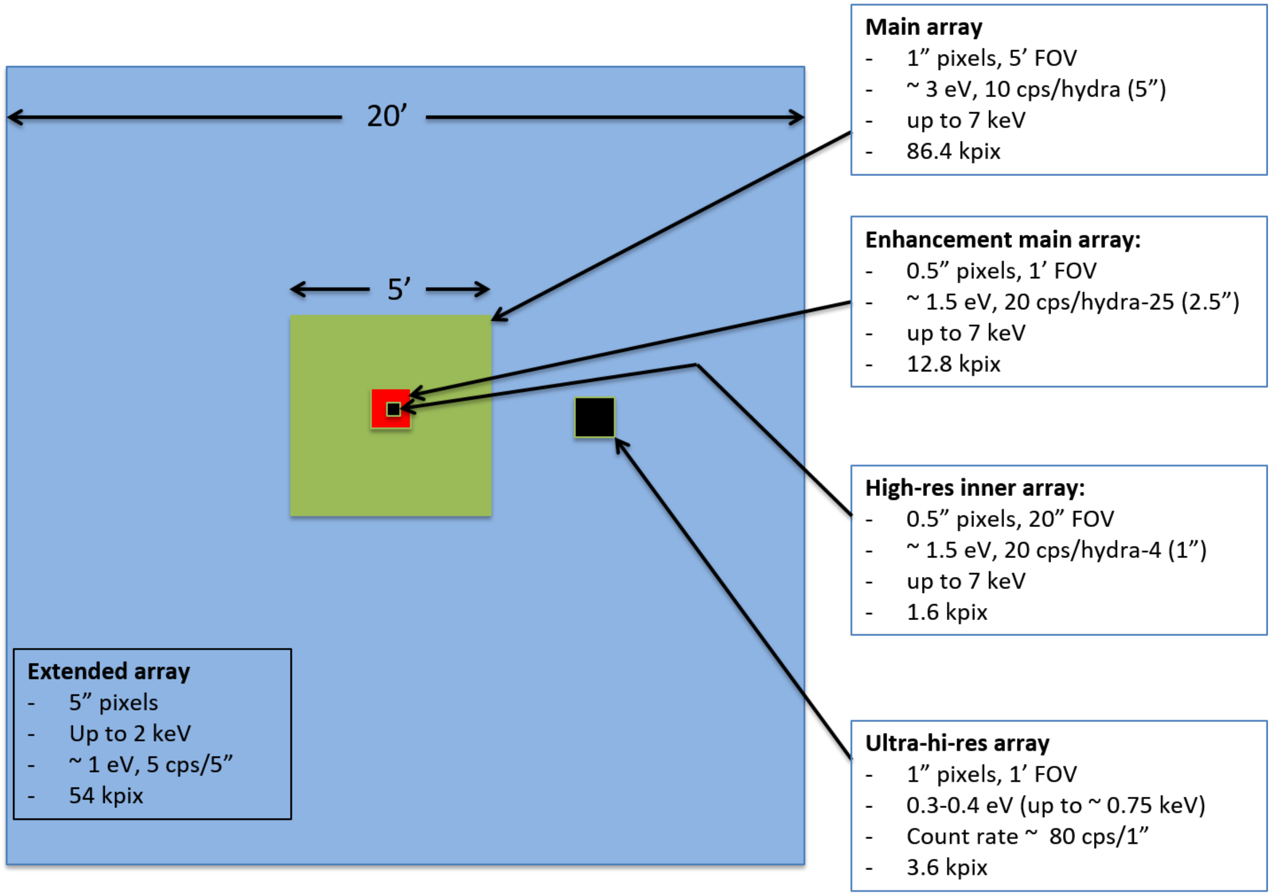
- X-ray Microcalorimeter Imaging Spectrometer (XMIS)
    - Instrument Design and Integration (Completed 1st IDL @ GSFC)





See Talks:

Lynx Science Instruments



See Talks:

High Definition X-ray Imager (Notional)

Energy Range	0.2 – 10 keV QE > 90% (0.3-6 keV), QE > 10% (0.2-9 keV)
FOV	22’ x 22’ (4k x 4k pixels)
Pixel Size	< 16 x 16 µm (≤ 0.33”)
Read Noise	≤ 4 e^-
Energy Resolution	37 eV @ 0.3 keV, 120 eV @ 6 keV (FWHM)
Frame Rate	> 100 frames/s (full frame) > 10000 frames/s (windowed region)
Radiation Tolerance	10 yrs at L2

X-ray Grating Spectrometer (Notional)

Effective Area	~4000 cm^2 @ 0.3 keV (63% azimuthal coverage)
Resolving Power, R	> 5,000
Energy Resolution	< 5 eV (FWHM)
Count Rate Capability	< 1 count/s/pixel
Array size	300 x 300 pixel array

Lynx X-ray Microcalorimeter (Notional

Pixel Size	1” (50 µm pixels for 10-m focal length)
FOV	At least 5’ x 5’
Energy Resolution	< 5 eV (FWHM)
Count Rate Capability	< 1 count/s/pixel
Array size	300 x 300 pixel array

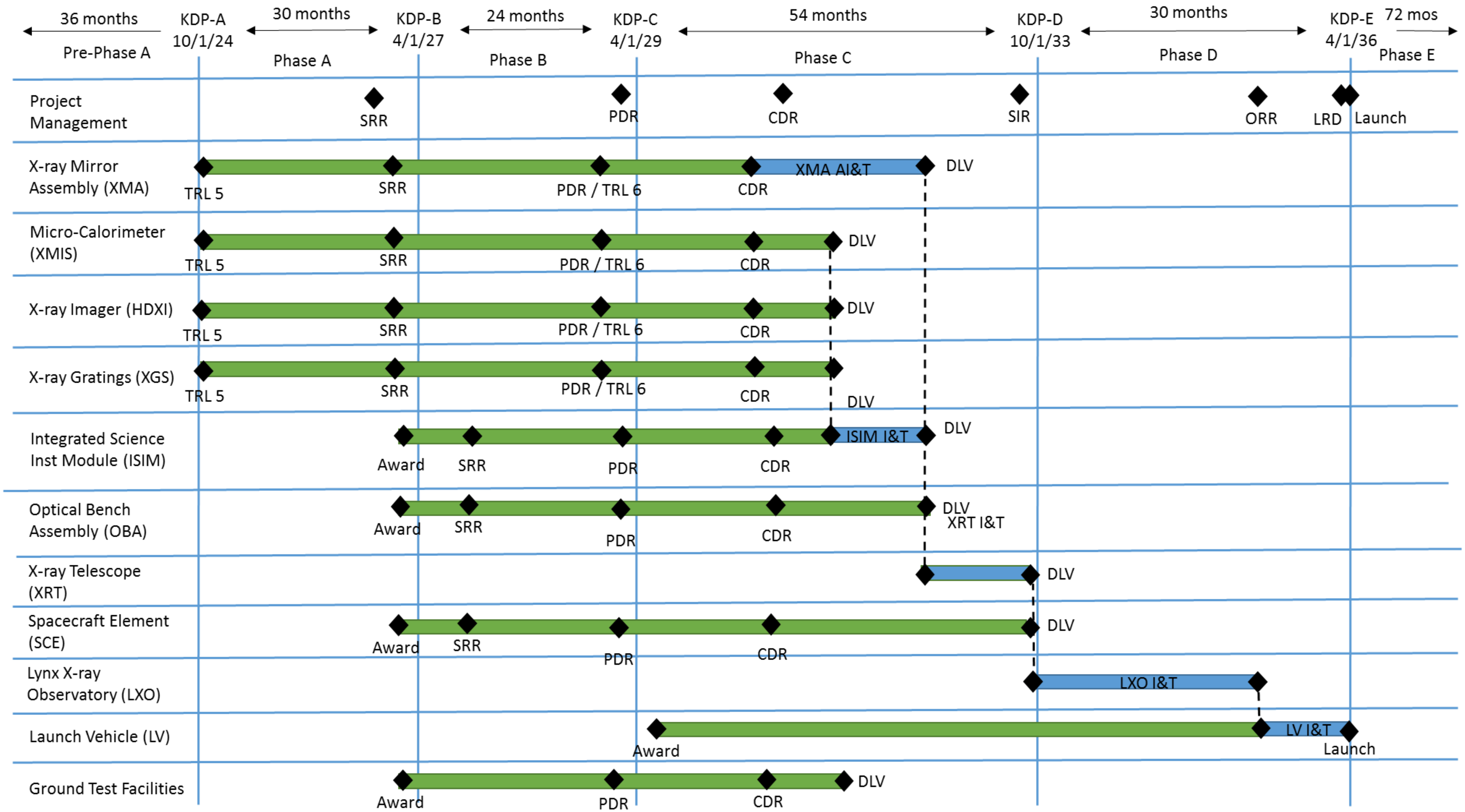
Mission Design

- *Mission Lifecycle (*Draft*)*
- *Mission Design* (MSFC ACO) + Trades
  - Structures [Launch vehicle Trade]
  - Thermal
  - Propulsion
  - Avionics [Comm Trade]
  - GNC [Rapid response capability Trade]
  - Power
  - Mechanisms [Moveable optics vs. instrument table Trade]
  - Environments [Orbit Trade]

***Model-Based Systems Engineering** Approach focused on Concept of Operations*

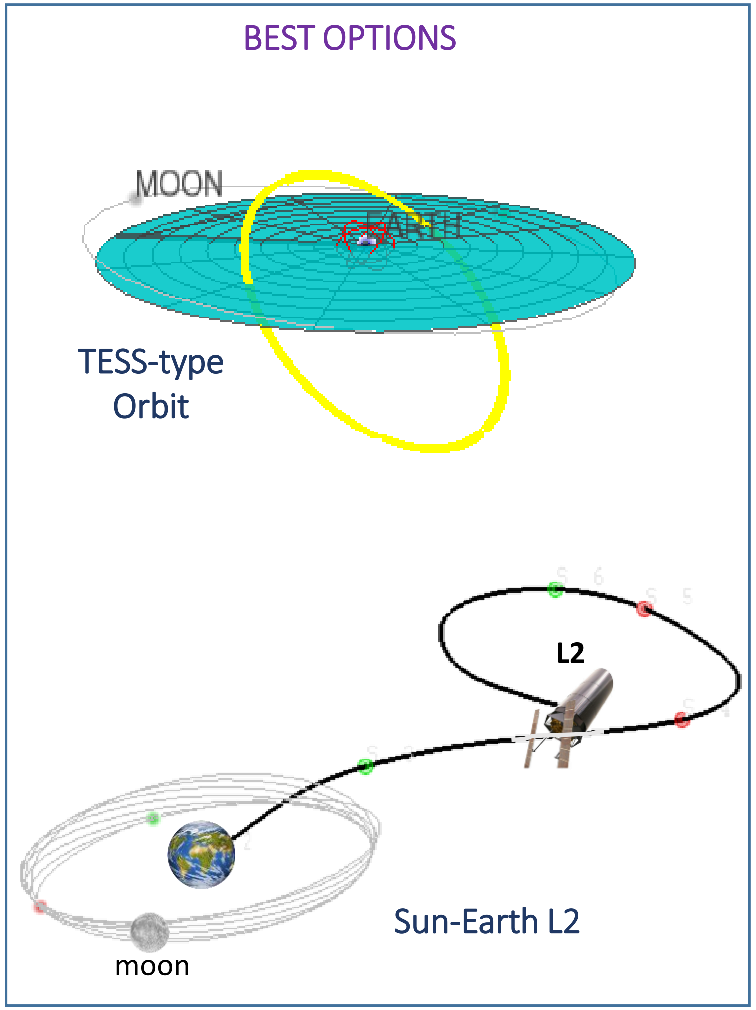
- WBS + dictionary
- Stakeholder Viewpoints
- System Block Diagrams
- System Interface Diagrams (internal and external)
- Use Diagrams
  - Manufacturing
  - AI&T (major sub-systems)
  - Ground Operations
  - Launch Integration
  - Launch Operations (launch, deployment, T&CO)
  - Mission Timeline
  - Science Operations
  - Off-nominal Operations
- Functional Block Diagrams
- System Requirements (Level 1 and 2)

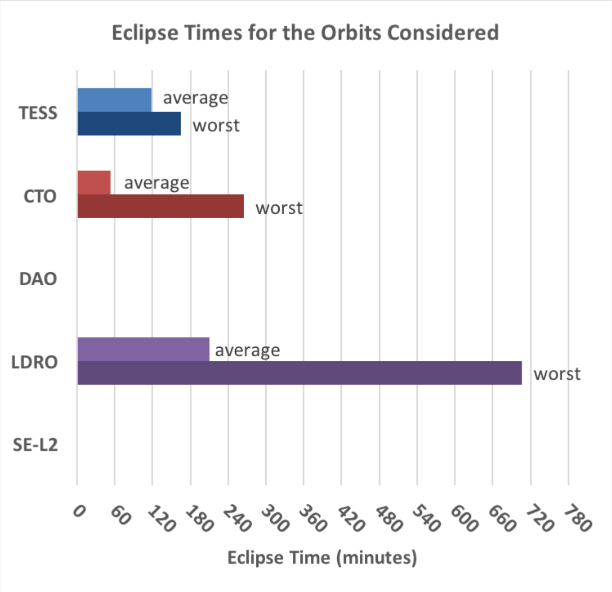
Lynx X-ray Observatory – Notional Mission Lifecycle Schedule

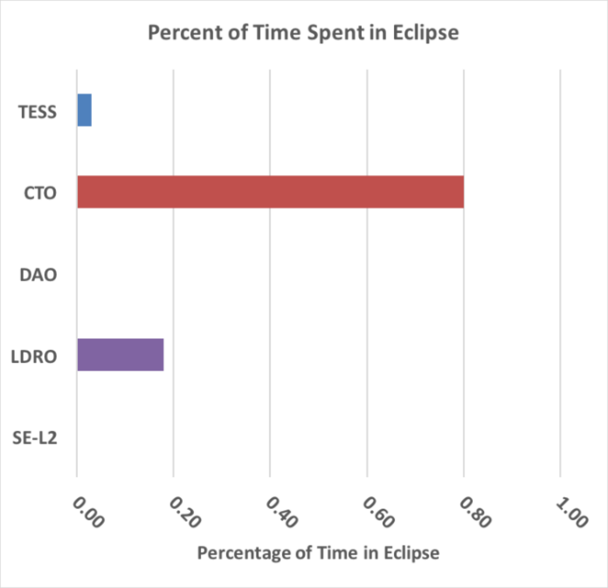


Mission Design

Orbit





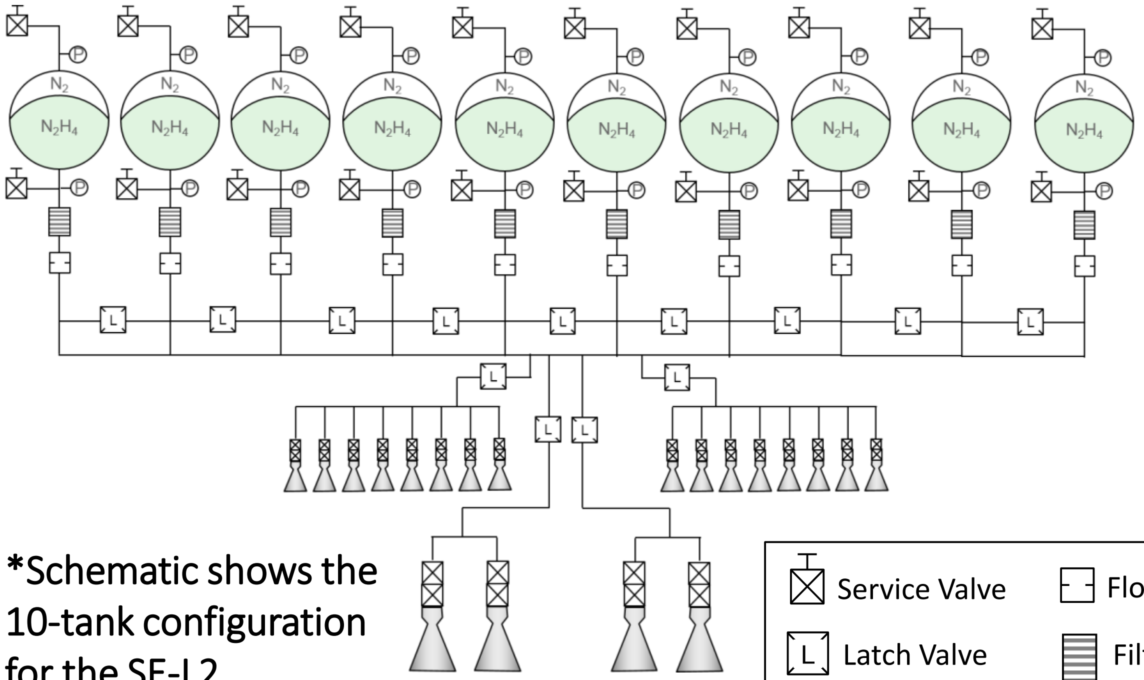


Orbit Trades

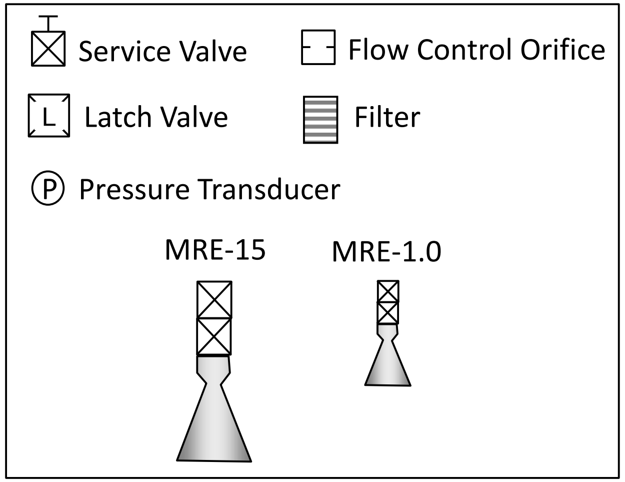
- •Launch Vehicle (Both)
- •Delta-V (SE-L2)
- •Thermal Environment (SE-L2)
- •Eclipsing (SE-L2, just)
- •Communications (TESS)
- •Meteroid Environment (Both)
- •Radiation Environment (average/worst case – TBD)
- •Serviceability (SE-L2)
- •Disposal (TESS)
- •Station Keeping (TESS)
- •Disturbance Environment (Both)

Mission Design

Propulsion



*Schematic shows the 10-tank configuration for the SE-L2 maneuver



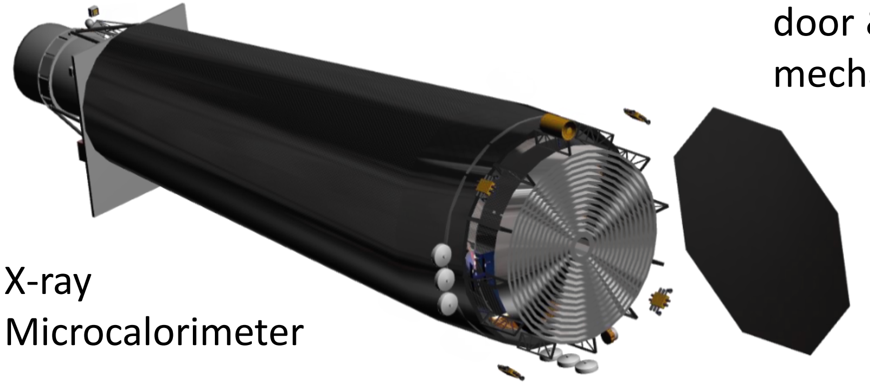
	SE-L2	TESS
Thrust (N)	66	66
Isp (s)	218	218
ΔV (m/s)	215.5	301.7
Propellant Mass (kg) -with 15% Margin-	661.4	907.9
Propellant Volume (in^3)	44,242	60,731
Propellant Tanks Needed	**10**	**13**

- Monopropellant blowdown system
  - Fuel = Hydrazine
  - Pressurant = Gaseous Nitrogen
- Maneuver assumed: SE-L2
  - ΔV required = 215.5 m/s
- Propellant mass for chosen maneuver
  - Hydrazine = 661.4 kg (includes 5% ACS tax and 10% margin)
- Engines
  - Main Engines: Northrop Grumman MRE-15
    - Thrust = 86 N at 27.6 bar, 66 N at 19.0 bar
    - Isp = 228 s at 19.0 bar
  - RCS/ACS Engines: Northrop Grumman MRE-1.0
    - Thrust = 5.0 N at 27.6 bar, 3.4 N at 19.0 bar
    - Isp = 218 s at 19.0 bar
- Mass estimated using flight-qualified components
  - Rough estimate made for feedlines and mounts/fittings

Mission Design

Integrated Science Instrument Module

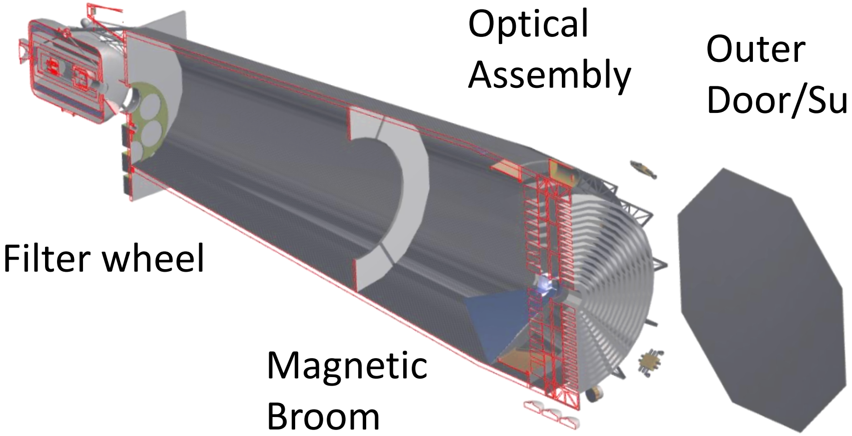
Mechanical



X-ray Microcalorimeter

Optical Assembly

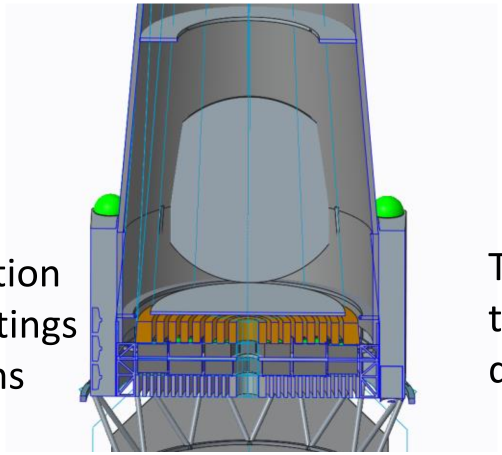
Outer Door/Sunshade



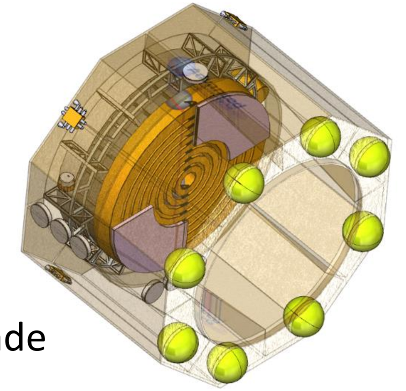
Filter wheel

Magnetic Broom

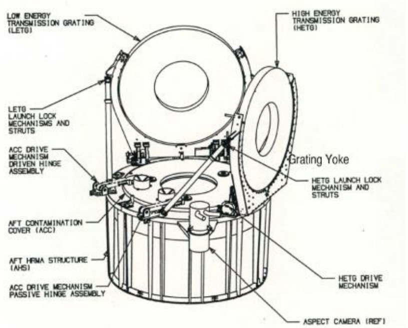
Internal contamination door & gratings mechanisms



Mono-prop tanks

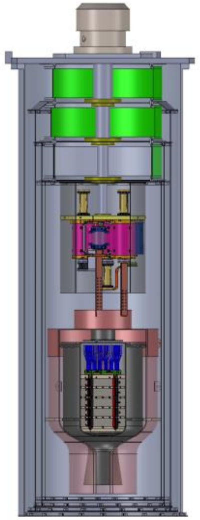


Chandra Heritage Considered

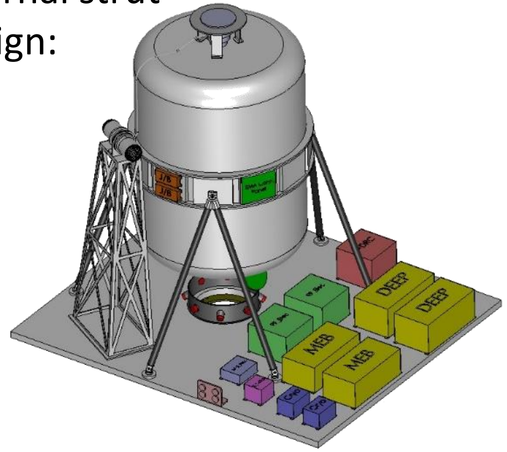


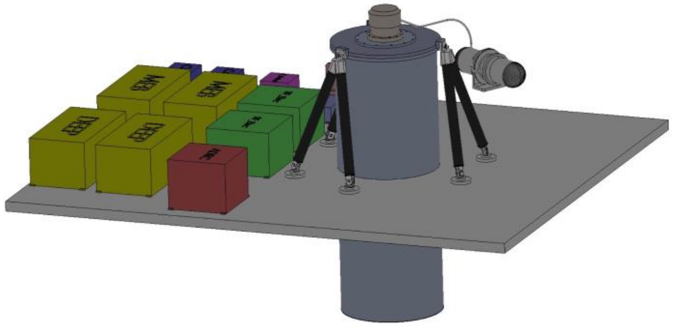
X-ray Microcalorimeter Designs

Thrust tube design:



Internal strut design:

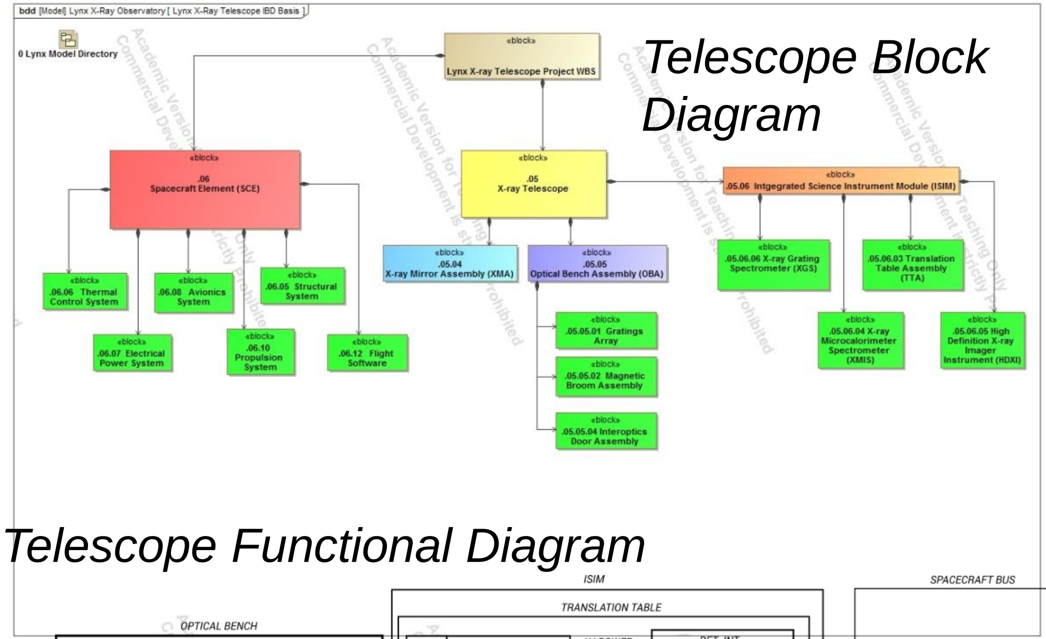




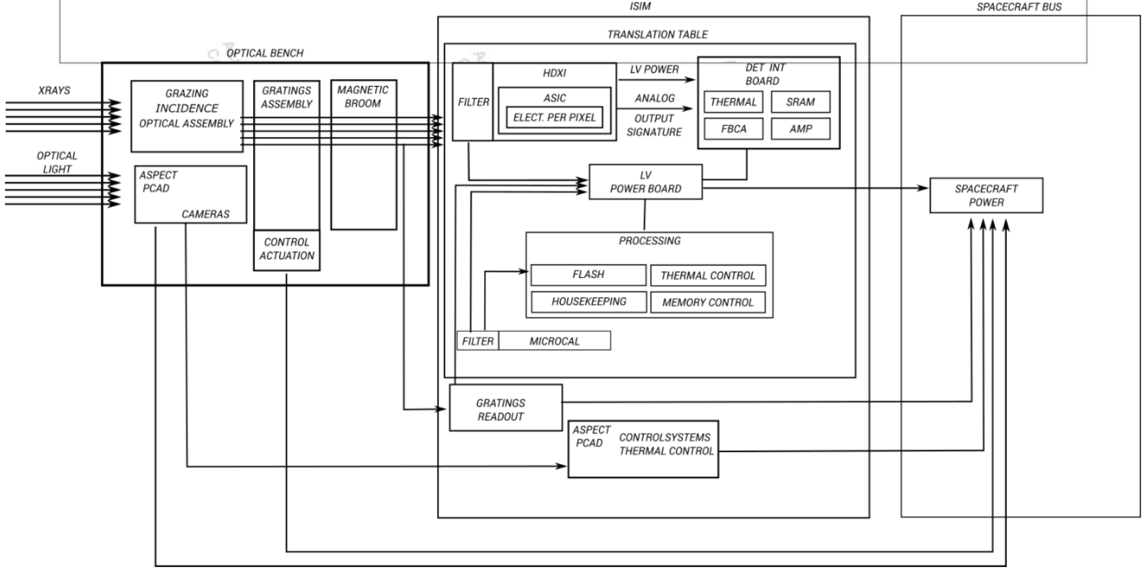
Filter wheel attached to bottom of the cryostat – with sufficient clearance for door

MBSE Output - Examples

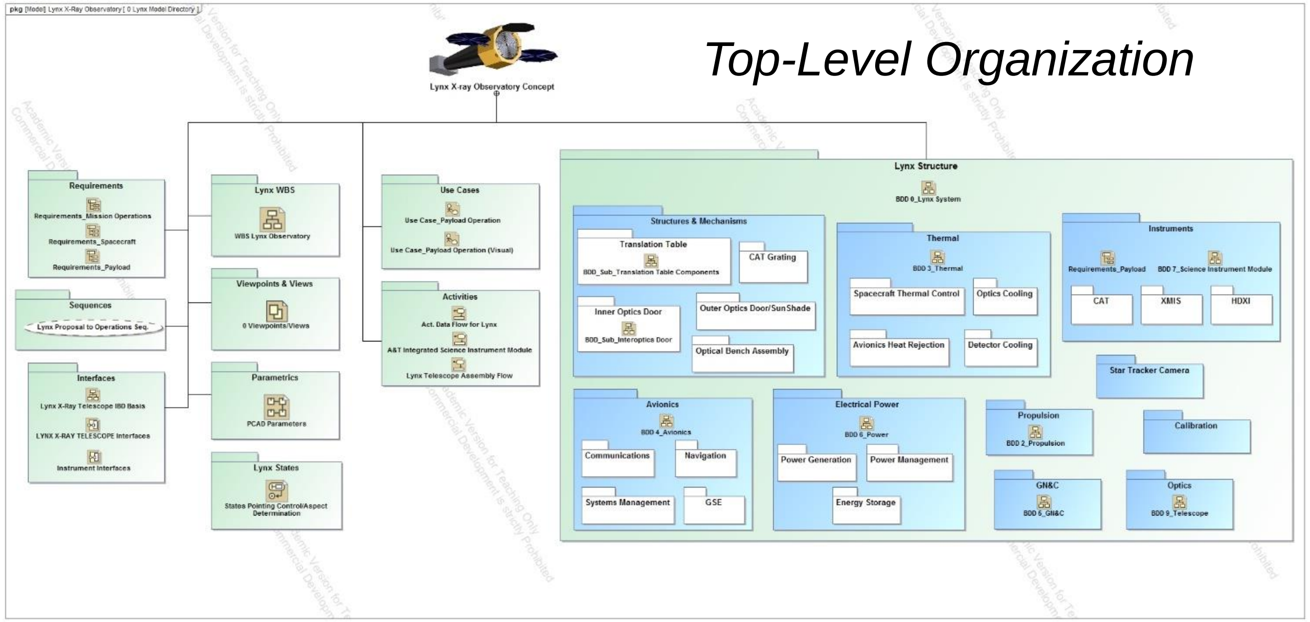
Telescope Block Diagram

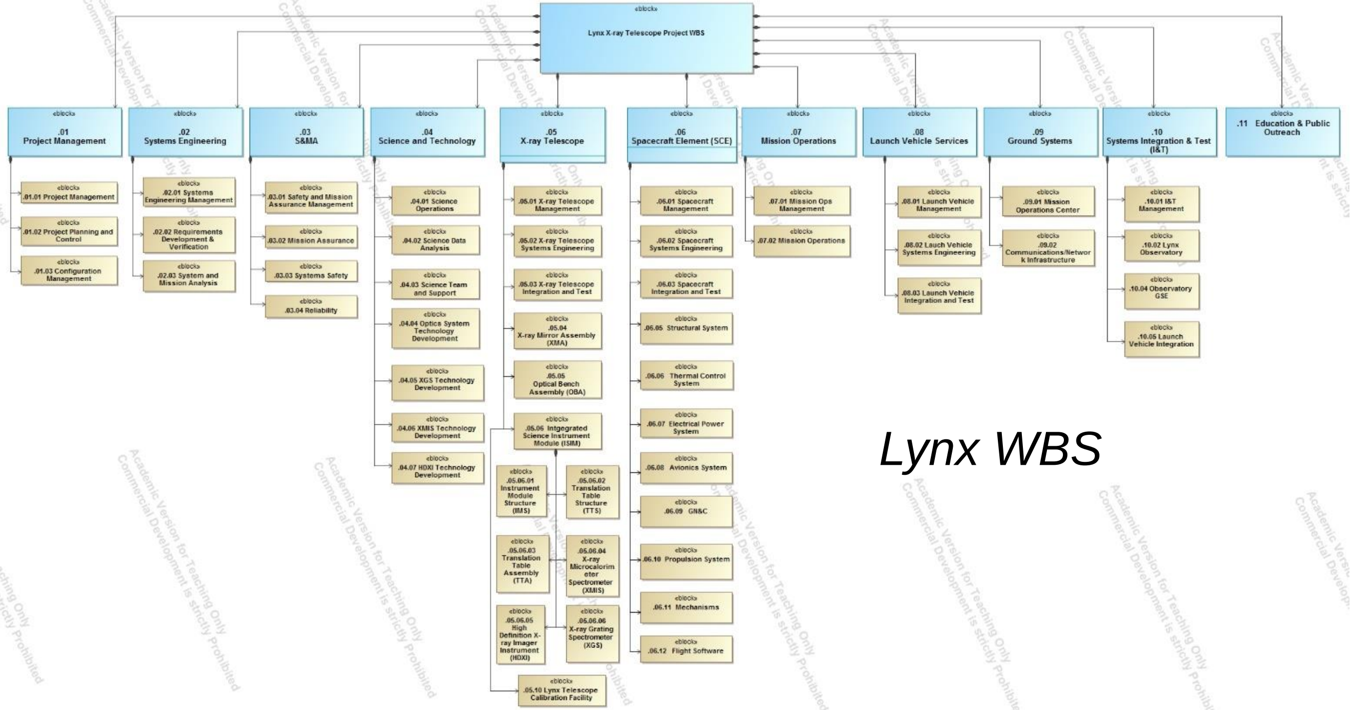


Telescope Functional Diagram



Top-Level Organization





Lynx WBS

Thank You!

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https://wwwastro.msfc.nasa.gov/lynx/